Progress with Single Footprint Retrievals using SARTA-Cloudy

Sergio DeSouza-Machado, Larrabee Strow

Department of Physics, JCET
University of Maryland Baltimore County (UMBC)

AIRS Science Team Meeting
March 2016
Pasadena CA

Outline

- Motivation
- Review of SARTA/TwoSlab vs PCRTM/MRO
  - Main diff is TwoSlabs vs 100 layers!!
  - $\omega < 1$ so mainly absorption, so PCLSAM is good fast approx
- Apply fast scattering code to Optimal Estimation Retrieval
- Improvements/updates from Oct 2015 AIRS STM talk
  - include super-saturation in cost function
  - Case Study : 2014/02/08
  - Starting out with AIRS $< L3_{10} >$ (10 year monthly averaged L3 climatology), retrievals move towards ECM and AIRS L2
  - Comparisons to (B. Kahn) L2 ice ods
- NEXT : Need to work on smoothing the results (improved cov matrices) ...

Motivation

- Most of AIRS data contains cloud and/or aerosol effects
- Current AIRS L2 retrieval uses black clouds to account for cloud effects
- Cloud retrievals can be complicated (need to guesstimate cloud top, amount, particle size,fraction, phase) typically for $N \leq 3$ cloud decks
- Scattering algorithms and cloud representation are additional complexity
- Here we use SARTA TwoSlab, with first guess from ECMWF in an Optimal Estimation Retrieval to improve retrieval yield on single footprints, with error diagnostics as part of output
- Can use different smoothing matrices (diagonal covariance, Tikonov, etc)

Reminders about scattering RTAs

- PCRTM and SARTA are fast RTAs (~ same speed)
- Optical Depths from PCRTM developed from LBLRTM, while SARTA ODs come from kCARTA
- PCRTM uses Re/Tr using DISORT, SARTA uses PCLSAM for scattering
    - Other groups use PCLSAM eg Marco Matricardi (ECMWF), Jerome Vidot (Meteo France)
- Both have clear sky mode, 2 slab mode, 100 layer MRO
- 2 slab mode : 4 streams/subpixels needed (cloud1,cloud2,cloud12,clear)
- MRO mode : multiple (~ 50) subpixels needed
- So TwoSlab is about 10 or more times faster than MRO, and jacobians are straightforward
- VERY EASY to move slab clouds up/down eg put them at mean of cloud profile? or at peak of "cloud weighting function"? etc

SARTA TwoSlab

D of F calculations show there are typically only 2-5 pieces of information per cloud (eg amount, top/bottom, some profile info) We have taken SARTA-clear and included PCLSAM (Parametrization for Cloud Long-wave Scattering for use in Atmospheric Models, Chou et. al, J. Climate v12m pg 159-169 (1999))

TOA radiance is weighted sum of at most FOUR radiance streams

$$r(\nu) = C_{11} r_1(\nu) + C_{22} r_2(\nu) + C_{12} r_1 2(\nu) + C_{00} r_{clr}(\nu)$$

where $C_{11} = C_1 - C_{12}$, $C_{22} = C_2 - C_{12}$,$C_{00} = 1 - (C_1 + C_2 - C_{12})$
so on average code is x2 slower than SARTA clear

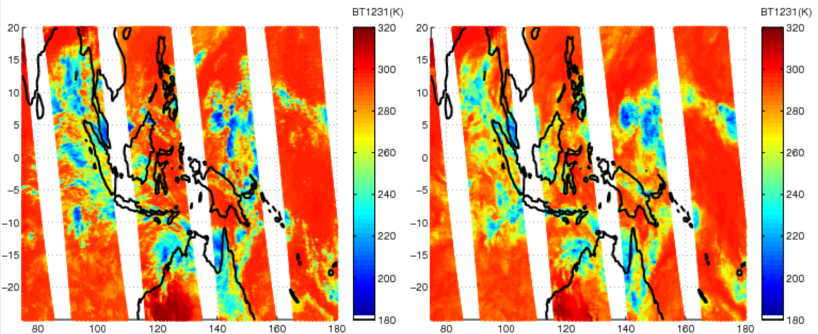
Cirrus scattering params from General Habit Model (GHM) from Ping Yang/ Bryan Baum (2013)

Water scattering params assume Mie scattering, with Particle Size Distribution from MODIS L2 model

TwoSlab NOT limited to PCLSAM .. can easily use eg DISORT

TWP G039 obs/calcs 2011/03/11

Left panel : AIRS observations. Right panel : SARTA 2S



General locations of the deep convection regions are correct, though there are substantially fewer DCC (cloud tops below 210 K) in the simulations.

Retrieval Idea

- Compute radiances using co-located ECMWF geo/cloud fields
- For each pixel, initial guess is as follows
  - Match "closest BT simulation" to AIRS obs, using some window, 15 μm, 6.7 μm channels
  - Keep geo-fields the same, swap in cloud fields from this "closest match"
  - Then keep fix cloud fraction, particle sizes, cloud top for the retrieval
- Run through OEM retrieval, solving for cloud amounts for two clouds, and T(z), WV(z), stemp(z), col O3, col CH4
- output diagnostics include AK, D of F
- jacs : column for stemp/CH4/O3/cloud amounts, 100 layers for WV(z),T(z)
- roughly 5 hours to do 12150 FOVS on one processor (1.5 sec per FOV), 100 layer jacs for WV and T, 300 channels
- but this is me just messing around, with NO optimization!!!!!

A few Retrieval Details

- Cost function
  $J = (y - F(x))^T S_\epsilon^{-1} (y - F(x)) + (x - x_a)^T R(x)^{-1} (x - x_a) + J_{sat}$
  (Rodgers textbook, Phalippou 1996 QJRMS)
- nonlinear Gauss-Newton iterative solution (Rodgers textbook)
- Further speed things up by using about 400 channels (so 6 min SARTA run → 1 min)
- once I have initial ERA/ECM state, I compute jacobians for all 12150 FOVS in big gulps
  - do all 12150 surface temp jacs in one go
  - do all 12150 cngwat1 (cloud amount1) jacs in next go
  - do all 12150 cngwat2 (cloud amount2) jacs in next go
  - do all 12150 column methane, ozone jacs in next go etc
  - loop through layer by layer to do the gas1(z), temp(z) jacobians
  - total $\simeq$ 200 jacs → 200 mins
- Covariance matrices (1K for temp, 10% for gas amounts)
  - right now using diagonal, can switch to Tikonov, exp decay etc
- Run off OEM, for N=5 iterations at most, save AK, dofs etc

What I did for 2014/02/08

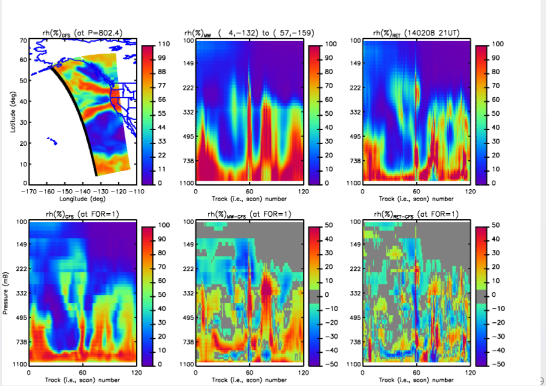
- Create RTP with ECM clouds and geothermal
- Swap for "best" clouds
- Replace thermodynamic with climatology from February Clim averaged over 10 years which should not know the intricate details of the events of that date (go from 24 T/O3, 12 WV to our 100 layers)
- Do retrieval, check results
- Switch back to ECM thermodynamic *a-priori*, do retrieval, check results

All daytime grans
Includes grans 220-222
Do only grans/FOVS with robs1 qualflag < 64

Feb 08, 2014 : Atmospheric River grans 220-222

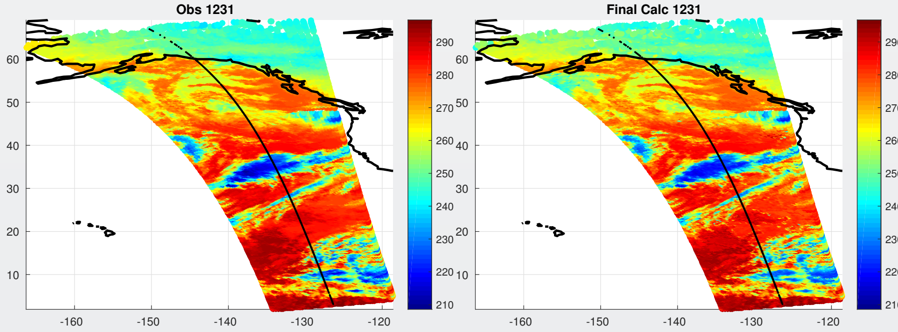
Recent analysis of the NOAA CrIS/ATMS EDRs in complex weather regimes Chris Barnet (STC), Wed May 14, 2014

Feb. 8, 2014 CrIS/ATMS Retrievals
(NOTE: ignoring QC for this movie)



G220-222 Start with Climatology

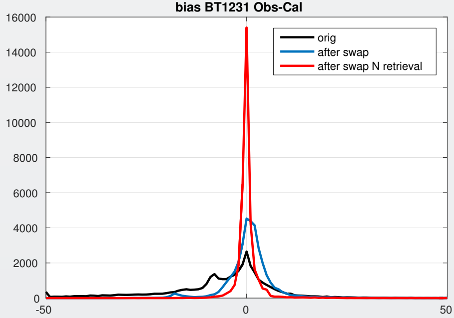
G220-222 BT1231
(L) OBS (R) CALC

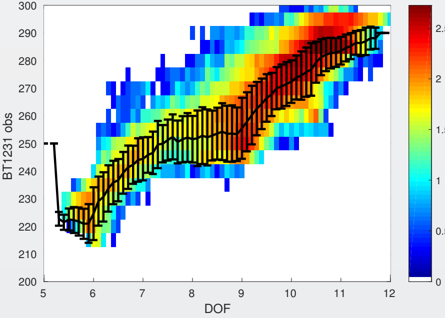


CRIS vs AIRS granules shifted, cannot do same transect C. Barnet did → use AIRS centerfovs

G220-222 Start with Climatology

G220-222 Effect of swapping cloud fields
(L) pdf of BT1231 cal (R) BT1231 vs DOF



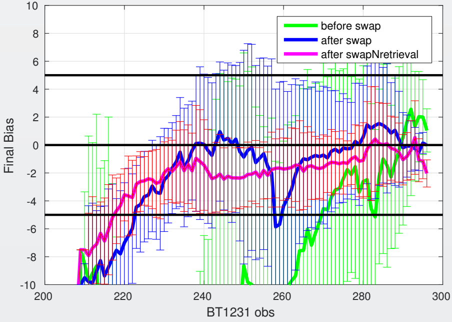


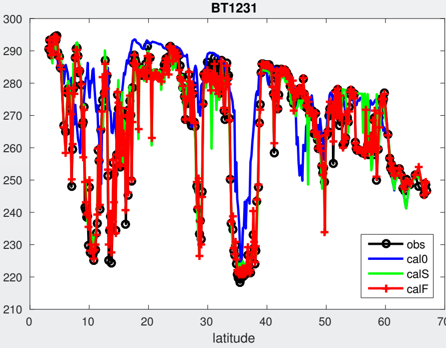
(L) raw calcs (black) improved by swap (blue) and retrieval (red)
(R) DOFs depend on BT1231 obs (thick clouds, not much I can do)

G220-222 Start with Climatology

G220-222 Effect of swapping cloud fields II

(L) BT1231 bias vs BT1231 obs (R) BT1231 along transect

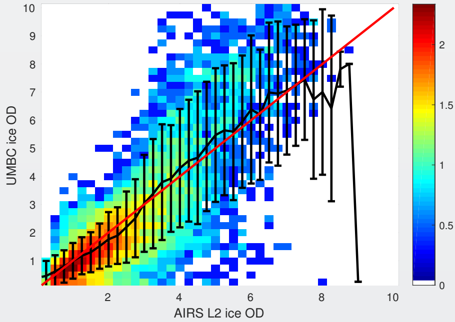


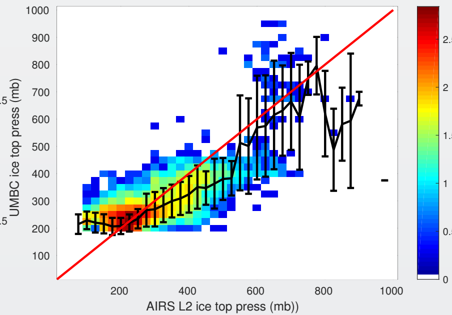


(L) green are raw calcs, improved by swap (blue) and retrieval (red)
(R) BT1231 obs(k), raw calcs(b), swap calcs(g), final calcs (r) along transect

G220-222 Start with Climatology

G220-222 Comparing Ice Cloud params against L2 products
(L) UMBC vs L2 iceOD (R) UMBC vs L2 ice ctop





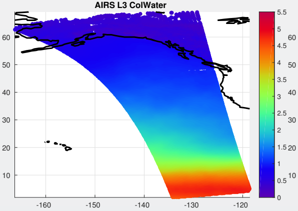
looks like L2 ice eff diam?? mostly between 50-80 um while I span 40-140 um, depends on ctop

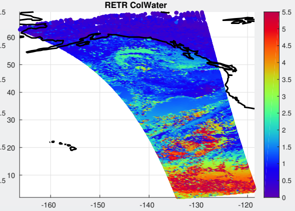
G220-222 Start with Climatology

G220-222 column water

(L) Clim

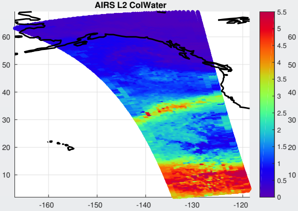
(R) UMBC RETR

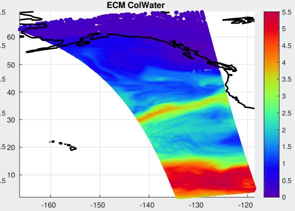




(L) AIRS L2

(R) ECM

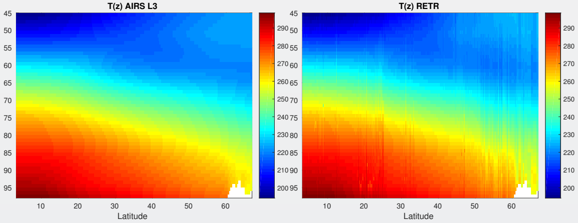




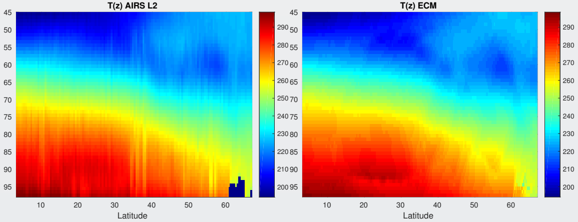
G220-222 Start with Climatology

G220-222 T(z) along transect (lay [44 76 97] 100,500,1000 mb)

(L) Clim (R) UMBC RETR



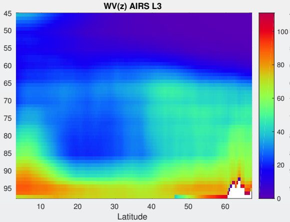
(L) AIRS L2 (R) ECM



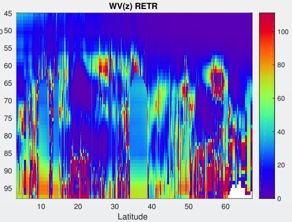
G220-222 Start with Climatology

G220-222 RH(z) along transect (lay [44 76 97] 100,500,1000 mb)

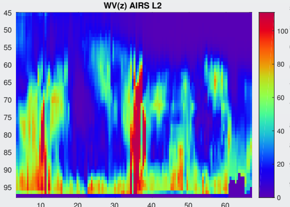
(L) Clim



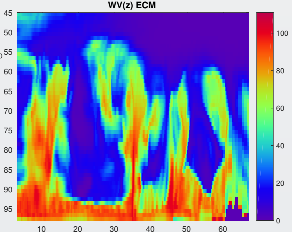
(R) UMBC RETR



(L) AIRS L2



(R) ECM



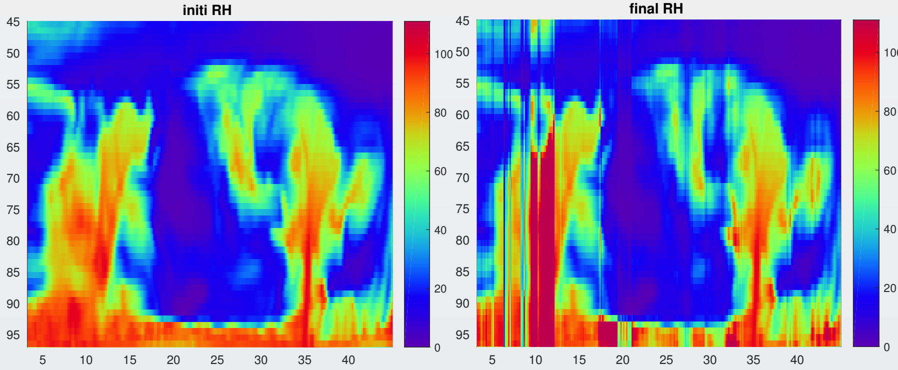
G220-222 Start with ECM

G220-222 RH(z) along transect (lay [44 76 97] 100,500,1000 mb)

Much cleaner!

Now need to tweak params!

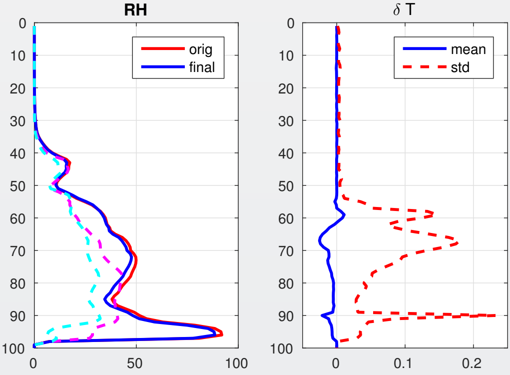
(L) ECM (R) UMBC



G220-222 Start with ECM

G220-222 Spectral space (TIR)

Much cleaner!



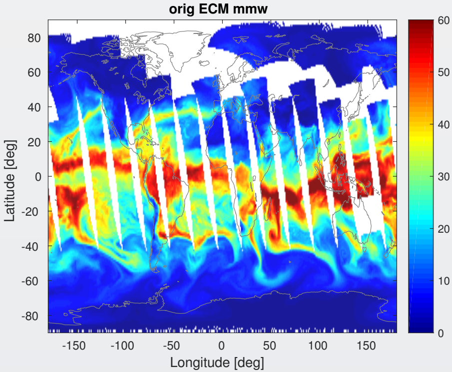
reduced bias significantly, but there are still outliers ....

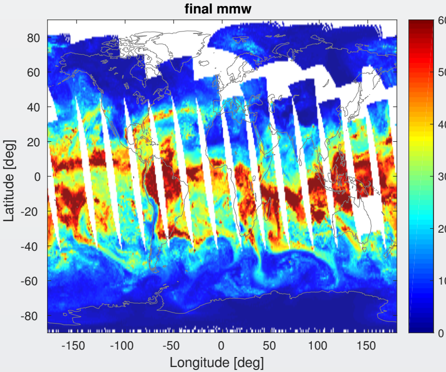
2014/02/08 Start with ECM

Daytime granules

Much cleaner!

(L) ECM (R) UMBC





Conclusions

- TwoSlab is very fast method, can be tweaked to statistically mimic MRO, or to improve bias comparisons with obs
- Can easily be used to compute jacobians for OEM
- Start with ECMWF geophysical fields, move cloud fields around according to comparisons between obs/cal
- Choose handful of channels, do 100 layer jacobians
- Output diagnostics include DOFs etc
- Starting with Climatology shows not sticking to *a-priori*
- Improvements (TBD)
  - trapezoid jacobians
  - pick channels more prudently
  - de-wiggle by tuning diagonal/covariance/tikonov matrices
  - add in eg *N* layer O3 to the retrieval
  - improve spectral bias and stddev!